Using Patch Analysis Methods to Detect Images Tampered with Seam Insertion

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ABSTRACT

Retargeting images by seam carving and seam insertion is hard to identify; therefore, detection of seam tampered images has been an important but challenging research topic. Aside from existing methods, i.e., those derived from steganography attacks and those based on statistical features, we have proposed a novel detection method in our previous work, referred to as the patch analysis method. This method divides images into 2×2 blocks, named as *mini-squares*, and then searches for one of nine patch types that is likely to recover a mini-square from seam carving. By analyzing the patch transition probability among three-connected mini-squares, we achieved currently best accuracies for detecting seam carved images. Here we extend the application of this method to detect images tampered with seam insertion. We will present and discuss the experimental results in this paper.

KEYWORDS

Seam Tampering Methods, Seam Carving, Seam Insertion, Content-Aware Image Processing, Digital Forensics, Steganography Attacking, Patch Analysis.

1 INTRODUCTION

Seam tampering methods [6], including *seam carving* and *seam insertion*, have attracted increasing attention in image retargeting and digital forensics research fields [1, 2, 3]. Seam tampering methods assign a Sobel-operator-based energy value to each pixel. Seams are defined as the eight-connected paths of pixels, either vertically from top to bottom or horizontally from left to right. Successive removal or duplication of the optimal seams, i.e., those seams with the lowest sum of energy, allows modification in not only the image size but also image contents. Figure 1 shows the effects by using seam carving and seam insertion methods. Pixels with lower energy are generally removed or duplicated earlier; implying that the modifications to the image are difficult to identify. Although difficult, it is important to design a seam tampering detection method.

For detecting images with seam carving, Sarkar et al. introduced a steganography attacking algorithm in 2009 [4]. This algorithm uses a 324-dimensional Markov feature consisting of 2D difference histograms in the 8×8 block-based discrete cosine transform domain for input into an SVM classifier system. This way, although proven to be well suited to steganography attacks ($> 96\%$ accuracy), yields accuracies of 70.4% and 77.3% for detecting 20% and 30% seam-carved images respectively. Then, Fillion and Sharma proposed some detection methods for seam-carved images in 2010 [2]. The basic idea behind these methods includes the bias of energy distribution, the dispersal of seam behavior, and the affection of wavelet absolute moments. These statistical features achieved higher detection accuracies of 84.0% and 91.3% for 20% and 30% seam-carved images respectively.

We proposed a patch analysis detection method in 2014 [7]. This method rolls back pixels removed during the seam carving process and results in the currently best detection accuracies, namely, 92.2%, 92.6% and 95.8%

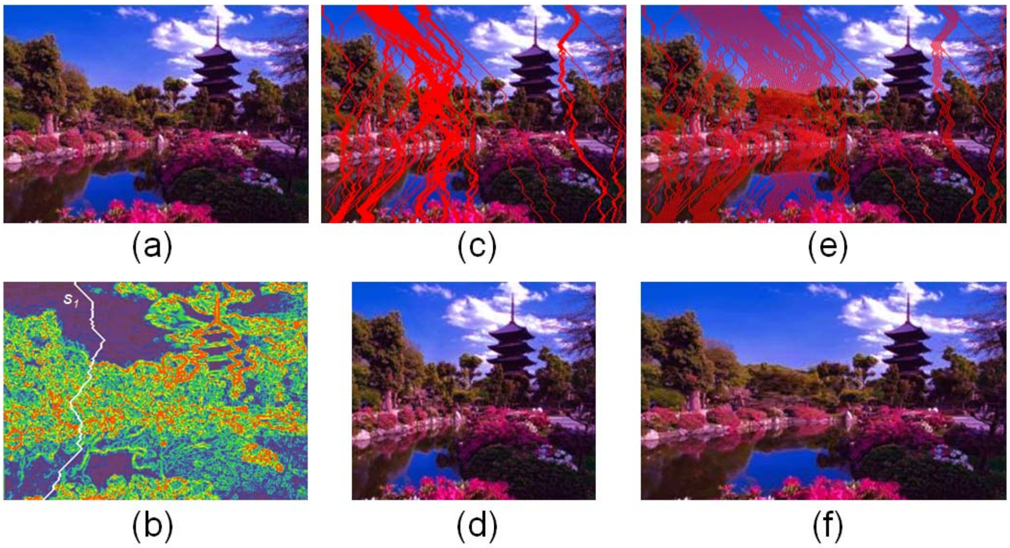

Figure 1. Seam Tampering Methods. (a) the original image, (b) energy map and the first seam s_1, (c) image with carved seams drawn in red, (d) image tampered with seam carving, (e) image with inserted seams drawn in red, (f) image tampered with seam insertion.

for 20%, 30% and 50% seam-carved images respectively. In this paper, we extend this method to detect images tampered with seam insertion. Experimental results reveal that the detection accuracies for seam insertion are all above 94% for all tampered images. We therefore conclude that the patch analysis method can also be used to detect seam-inserted images.

2 PATCH ANALYSIS DETECTION METHOD

The patch analysis detection method first converts the test image into its intensity component I, and then divides I into 2×2 blocks called *mini-squares*. A mini-square, $S_{i,j}$, is defined as follows:

$$S_{i,j} = \begin{bmatrix} I_{2i,2j} & I_{2i,2j+1} \\ I_{2i+1,2j} & I_{2i+1,2j+1} \end{bmatrix}. \quad (1)$$

For each mini-square, we have nine types of 2×3 patches that roll it back from possible seam carving effects. These patches can be constructed by interpolation between adjacent pixels. The patch operators, P^k for $k \in \{0, 1, \cdots, 8\}$ are given by the following equation with $p = 2i$ and $q = 2j$:

$$P^k_{S_{i,j}} =$$

$$\begin{cases}
\begin{bmatrix} (I_{p,q-1}+I_{p,q})/2 & I_{p,q} & I_{p,q+1} \\ (I_{p+1,q-1}+I_{p+1,q})/2 & I_{p+1,q} & I_{p+1,q+1} \end{bmatrix} & if \quad k=0, \\
\begin{bmatrix} (I_{p,q-1}+I_{p,q})/2 & I_{p,q} & I_{p,q+1} \\ I_{p+1,q} & (I_{p+1,q}+I_{p+1,q+1})/2 & I_{p+1,q+1} \end{bmatrix} & if \quad k=1, \\
\begin{bmatrix} (I_{p,q-1}+I_{p,q})/2 & I_{p,q} & I_{p,q+1} \\ I_{p+1,q} & I_{p+1,q+1} & (I_{p+1,q+1}+I_{p+1,q+2})/2 \end{bmatrix} & if \quad k=2, \\
\begin{bmatrix} I_{p,q} & (I_{p,q}+I_{p,q+1})/2 & I_{p,q+1} \\ (I_{p+1,q-1}+I_{p+1,q})/2 & I_{p+1,q} & I_{p+1,q+1} \end{bmatrix} & if \quad k=3, \\
\begin{bmatrix} I_{p,q} & (I_{p,q}+I_{p,q+1})/2 & I_{p,q+1} \\ I_{p+1,q} & (I_{p+1,q}+I_{p+1,q+1})/2 & I_{p+1,q+1} \end{bmatrix} & if \quad k=4, \\
\begin{bmatrix} I_{p,q} & (I_{p,q}+I_{p,q+1})/2 & I_{p,q+1} \\ I_{p+1,q} & I_{p+1,q+1} & (I_{p+1,q+1}+I_{p+1,q+2})/2 \end{bmatrix} & if \quad k=5, \\
\begin{bmatrix} I_{p,q} & I_{p,q+1} & (I_{p,q+1}+I_{p,q+2})/2 \\ (I_{p+1,q-1}+I_{p+1,q})/2 & I_{p+1,q} & I_{p+1,q+1} \end{bmatrix} & if \quad k=6, \\
\begin{bmatrix} I_{p,q} & I_{p,q+1} & (I_{p,q+1}+I_{p,q+2})/2 \\ I_{p+1,q} & (I_{p+1,q}+I_{p+1,q+1})/2 & I_{p+1,q+1} \end{bmatrix} & if \quad k=7, \\
\begin{bmatrix} I_{p,q} & I_{p,q+1} & (I_{p,q+1}+I_{p,q+2})/2 \\ I_{p+1,q} & I_{p+1,q+1} & (I_{p+1,q+1}+I_{p+1,q+2})/2 \end{bmatrix} & if \quad k=8,
\end{cases} \quad (2)$$

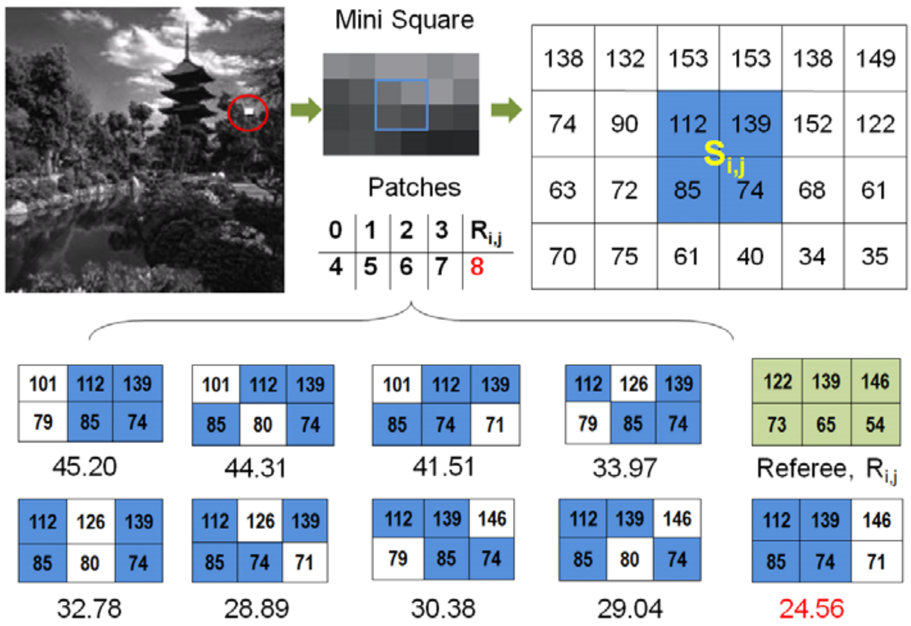

Figure 2. Selection of the Optimal Patch. For a 2×2 mini-square, $S_{i,j}$, we refer to its surrounding pixels and construct a 2×3 referee pattern, $R_{i,j}$, (eqn(3)). There are nine manners patching the mini-square to the referee pattern (i.e., 9 patch types numbered from 0 to 8). In this example, we select the optimal type using Euclidean distance as the criterion (eqn(4)). We list the distance in the bottom of its corresponding patch type. The eighth type is selected as the optimal for it results in the minimum distance.

There is a referee pattern for deciding the optimal patch type. The referee pattern, $R_{i,j}$, is a 2×3 image pattern generated from the local area of the corresponding mini-square:

$$R_{i,j} = \frac{1}{4}\sum_{a=0}^{1}\sum_{b=0}^{1} \begin{bmatrix} I_{2i-1+a,2j-1+b} & I_{2i+1+a,2j-1+b} \\ I_{2i-1+a,2j+b} & I_{2i+1+a,2j+b} \\ I_{2i-1+a,2j+1+b} & I_{2i+1+a,2j+1+b} \end{bmatrix}^T . \quad (3)$$

Using Euclidean distance as the criterion, we assign each mini-square one type number, $T(S_{i,j})$, to indicate the optimal patch type:

$$T(S_{i,j}) = \min_k D(R_{i,j}, P^k(S_{i,j})), \quad (4)$$

where

$$D(A,B) = ||[row_0(A)\ row_1(A)] - [row_0(B)\ row_1(B)]||.$$

We can consequently calculate three *patch transition probability matrices* that connect the mini-squares in three directions, namely, subdiagonal, vertical, and diagonal. Readers can refer to [7] for details.

The entries in these three 9×9 matrices, together with the probabilities of the nine types, form a 252-dimensional detection feature. This feature is sent to an SVM classifier system that detects whether the test image has been seam carved. While our description only focuses on detecting those images with vertical seam carving, the proposed method can be used to detect horizontal seam removal in a similar manner.

3 EXPERIMENTAL RESULTS AND DISCUSSION

We used the UCID image database [5] for the experiments, which comprised 1338 color images in total. All the images are with 384×512 pixels in size. In our previous work [7, 8], we developed the patch analysis method to detect images tampered with seam carving and achieved the best detection accuracy in the current stage. Here we extend the application of this method to detect images that are modi-

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Table 1. Seam carving and seam insertion detection accuracies result from our method.

	Test				
Train	10%	20%	30%	50%	mixed
(a) Seam Carving					
10%	64.87	60.15	62.15	70.45	64.40
20%	64.76	92.21	93.11	95.21	86.32
30%	65.28	84.42	92.61	95.28	84.40
50%	61.54	73.08	74.53	95.84	76.25
mixed	71.36	83.78	94.82	95.96	86.48
(b) Seam Insertion					
10%	94.16	95.66	96.33	96.14	95.57
20%	92.62	96.52	97.30	97.49	95.98
30%	88.80	95.17	97.53	98.01	94.88
50%	78.46	87.64	94.94	98.28	89.83
mixed	94.34	95.66	96.22	96.33	95.64

fied with seam insertion. The experimental results listed in table 1 show high detection accuracy for seam-inserted images as well as seam-carved images.

The essential part of our method is the feature extraction. Originally, we used patch types to trace the evidence during seam carving operation. As pixels are removed in paths on a seam-carved image, these evidences are cumulated over the modified regions and then we can use transition probability matrices to analyze the image. In this paper, we conducted further experiments that used patch analysis to detect seam-inserted images and resulted in above 94% accuracies for all images tampered with less than 50% insertion rate. Evidences built upon patch types are conclusively also available for detecting images with seam insertion.

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